Report for 2001SD1941B: Alternative Conservation Practices to Improve Soil and Water Quality

- Other Publications:
  - Kathol, John. 2002. Using a Precipitation-Runoff Model to Predict Runoff for Frequency Based Storms. South Dakota State University Agricultural and Biosystems Engineering Special Topics Course #795, Brookings, South Dakota.

Report Follows:

Abstract

The overall goal of the project was to monitor water quantity and quality discharges from small agricultural watersheds and compare results to the practices used on the watershed. Section 104 funds provided for operation, labor, and some equipment. Matching funds were obtained from the SD Corn Utilization Council (SDCUC). Monitoring equipment was installed on three waterways – one with a grassed waterway together with drain tile, one with drain tile but without grass, and one without tile or grass. Water quality samples were collected from tile discharge in 2001 and 2002. No runoff events were recorded in 2001. Runoff was measured on two of the watersheds in 2002. Results indicate that practices such as grassed waterways and subsurface tile drainage can reduce surface runoff from small agricultural watersheds in Eastern South Dakota.

Field installation and data collection

Waterways were selected to provide a range of practices but still be somewhat similar. Three cooperators were selected in cooperation with the SDCUC and the Farm Bureau. All watershed sites were in Moody County in Eastern South Dakota. Topographic maps were completed at all three sites using GPS survey equipment. All watersheds were planted to row crops. A 31-acre watershed with a grassed waterway and subsurface drainage was selected northwest of Flandreau, SD. The other two watersheds were southeast of Flandreau and were about 3000 feet apart. The second watershed was 33 acres and had subsurface drainage but no grassed waterway. The final watershed was 46 acres with neither grass nor subsurface drainage. Some small linear wetlands were embedded in the waterway.

Four automatic water samplers were purchased with three having bubbler options to provide water flow rate in addition to collecting water quality samples. H-flumes were constructed complete with approach sections and bubbler wells. These were installed at the outlet of each waterway during late June and early July, 2001, along with a continuous recording rain gage. A sampler collected tile outflow from the grassed waterway in 2001. In 2002 another sampler was loaned to the project so that tile outflow could be sampled at both sites that had tile.

The watershed with the tile and grass waterway had been recently reshaped, reseeded, and tile installed in 2000. Figure 1 is a photo of the flume and sampler being installed at the outlet of the waterway. A second sampler was installed at this site to collect water quality samples from the tile outflow. Figures A1 and A4 are aerial pictures and topographic maps, respectively, of the watershed area. General soil types were Moody silty clay loam and Houdek clay loam with Davison-Crossplain silt loams in the waterway areas.

The site having the waterway with tile drainage but no grass had been cropped for many years without any visible erosion in the waterway. The waterway had very flat side slopes with no clearly defined channel. Figure 2 is a picture of the waterway outlet and sampling equipment. Figures A2 and A5 are aerial pictures and topographic maps, respectively, of the watershed area. An established tile line was underneath the waterway. Soils in this watershed were predominantly Moody silty clay loam with some Wakonda-Chancellor silty clay loams.

Figure 2 - Installation of sampling equipment on tile/grass waterway.

Figure 1 - Installation of sampling equipment on tile-only wterway.

The third watershed included a waterway with neither grass nor tile drainage. Figures A3 and A6 are aerial pictures and topographic maps, respectively, of the watershed area. Embedded wetlands existed in the waterway. Soils were Moody-Trent and Moody silty clay loams with Wakonda-Chancellor silty clay loams through the waterway areas.

Water quality samples were collected during runoff events and were analyzed at the Water Quality Lab at SDSU. Samples were tested for conductivity, nitrogen, and phosphorus. Table 2 is a summary of the water quality analysis from the tile outlet samples. Table 3 is a summary of the water quality analysis from the surface runoff samples.

In general, precipitation during the 2001 and 2002 summers was below normal. Table 1 gives the monthly precipitation for the two growing seasons recorded by the NWS observer at Flandreau, SD. In 2001 April and June precipitation was above normal. A significant rainfall/runoff event the middle of June came before the equipment was installed. After the samplers were installed in 2001, no significant runoff event occurred before the samplers were removed in October. A November rain/snow event created runoff but was not recorded. Three water samples were analyzed from the tile outlet at the grassed waterway site.

2002 precipitation was below normal except for August and October. Nine runoff events were recorded at the untreated waterway in April, May, June, August and October. Only two runoff events occurred at the grassed waterway, one in June and one in August. No runoff events occurred at the tile-only waterway. Water quality samples were analyzed from the tile outlets at each of the tiled waterways (Table 2).

Table 1 – Monthly growing season precipitation in inches at Flandreau, SD.

MONTH	**NORMAL**	**2001**	**2002**
April	2.22	7.84	1.52
May	3.00	2.57	1.91
June	3.84	5.07	3.67
July	3.37	1.65	0.74
August	3.06	0.36	7.93
September	2.55	2.33	0.76
October	2.05	1.00*	3.11
TOTAL	**20.09**	**18.72**	**19.64**

* Estimated from nearby station

Results

The three waterways in this project were similar in size and had similar soils, but were different in slope and runoff characteristics. No direct comparison was possible between the waterways. In fact, it would be very difficult to find waterways that would permit statistical comparisons. No runoff was measured from the tile-only waterway and only two significant runoff events occurred on the tile and grass waterway. The untreated waterway had numerous runoff events, some even with small rainfall totals. Tile drainage appeared to reduce the runoff potential with similar rainfall events.

Water quality samples were collected from the tile outflow beneath the grassed waterway on three dates in 2001 (Table 2). Tile flow was intermittent after the first week in July. Nitrate concentrations were consistent between 14 and 15 parts per million (ppm). Even though the concentration was above the drinking water standard of 10 ppm, it was near the concentration that is favorable for plant uptake of nitrogen. Total phosphorus was measured at 0.01 and 0.02 ppm where the detection limit was 0.01. Electrical conductivity of the effluent water was about 1000 micromhos/cm for the three samples.

In 2002 samples of the tile flow were collected at the tile outlets of the two waterways with tile drainage (Table 2). At the tile and grass waterway, nitrate concentrations were below 10 ppm except for the last sample which followed a 2.56 inch rainfall. Electrical conductivity decreased during the course of the season. At the tile-only waterway, nitrate levels were from 13 to 17 ppm except for the last sample in July which was about 12 ppm. Conductivity varied from about 850 to 1370 micromhos/cm. Phosphorus in tile effluent was not tested in 2002 because the levels were near the lower detection level in 2001. Phosphorus levels in surface runoff averaged more than 100 times the tile concentration. Tile flow was intermittent after the first week in July in 2002.

Table 2 – Water quality analysis of tile outflow samples.

	NITRATE	**TOTAL PHOSPHORUS**	**ELECTRICAL CONDUCTIVITY**
GRASS/TILE WATERWAY	ppm	ppm*	micromhos/cm
2001 YEAR			
6/23	14.73	0.01	990
6/29	14.90	0.01	1008
7/5	14.04	0.02	1023
2002 YEAR			
4/16	1.55		1774
5/4	5.26		1417
5/21	8.62		1098
6/28	19.95		869
TILE ONLY WATERWAY			
2002 YEAR			
5/27	15.67		1122
6/12	16.59		1166
6/23	16.13		1292
7/12	11.99		849
8.28	13.61		1339
10/7	13.00		1368

* Detection limit = 0.01 ppm

In 2001 no runoff occurred during the time that the samplers were installed. In 2002 surface runoff samples were collected during two rainfall/runoff events on the tile and grass waterway and seven events on the untreated waterway (Table 3). The a, b, and c samples were at different time intervals during the same event. At the tile/grass waterway, nitrate levels were below one ppm and conductivity was low. Total phosphorus was about 1.6 ppm and total Kjeldahl nitrogen was about four ppm. At the untreated waterway, nitrate concentrations of the samples did not exceed the drinking water standard and were highest during the June 8 event at about 8 ppm. Total Kjeldahl nitrogen ranged from about one ppm to over 35 ppm. Total phosphorus varied from less than one ppm to over 12 ppm. Both varied several fold within one runoff event.

Table 4 lists the runoff events when measurable runoff occurred on the two waterways in 2002. Only two runoff events occurred on the tile/grass watershed. No surface runoff occurred from the tile-only watershed even though rainfall events were similar on this watershed compared to the untreated watershed that was only 3000 ft away. Surface runoff from the untreated watershed occurred nine times with many other small flows not being measurable. At times a small continuous flow discharged from the watershed. Not all flow from the waterway was recorded because the diversion berms overtopped during some events and some flow bypassed the flume. The untreated waterway was prone to runoff even with small rainfall events as evidenced by the May 11 rainfall of 0.16 inches with about 5% running off.

Table 3 – Water quality analysis of surface water runoff in 2002.

	NITRATE	**TKN***	**TOTAL PHOSPHORUS**	**ELECTRICAL CONDUCTIVITY**
GRASS/TILE WATERWAY	ppm	ppm	ppm	micromhos/cm
6/21a**	0.79	3.83	1.66	99
6/21b	0.90	4.26	1.61	66
8/21a	0.06	1.13	0.34	179
8/21b	0.02	1.16	0.27	69
UNTREATED WATERWAY				
4/16a	1.70	35.56	12.66	1032
4/16b	4.05	6.18	1.89	1084
4/21	3.17	9.19	2.81	1245
5/8	0.98	13.91	3.68	896
5/11	0.91	1.57	0.43	1412
6/3	2.50	2.52	0.46	1913
6/8a	1.81	10.41	3.80	867
6/8b	8.70	5.30	1.20	1472
6/8c	7.50	3.45	0.65	1577
8/6	2.14	7.28	2.40	383
8/21	1.52	6.25	1.88	343
10/4a	7.08	3.49	0.79	599
10/4b	4.19	2.39	0.65	715

* Total Kjeldahl Nitrogen
** letters indicate multiple samples during same event

Appendix B contains precipitation and runoff hydrographs for events at the watersheds. Additional data is included in the addendum report. Further study would be beneficial to evaluate more watersheds and more runoff-producing events. The impact of waterway practices and watershed management needs to be tested on different watersheds with different soils, topography, and management.

A detailed analysis of the watershed runoff characteristics is contained in the addendum report to this report. The addendum report outlines a procedure for calibration of the watershed using the HEC-HMS model and actual runoff data from the two watersheds that had runoff. Calibration of the model then allowed prediction of runoff resulting from standard design storms. Results of the modeling indicated that field practices and management change the runoff characteristics of watersheds. It is important to note that the calibration of the parameters for the watersheds returned values that did not necessarily match with values routinely used to predict runoff from small agricultural watersheds. For example, NRCS curve numbers typically used to predict runoff are much higher than those returned from the calibration. Calibration of specific watershed runoff characteristics may be necessary to accurately predict runoff from small agricultural watersheds in Eastern South Dakota.

Table 4 – Summary of runoff events in 2002.

DATE	PEAK RAINFALL INTENSITY	TOTAL RAINFALL	PEAK DISCHARGE	TOTAL RUNOFF VOLUME	PERCENT RUNOFF
	GRASS/TILE				
6/21	8 in/hr	2.56 in	1.41 cfs	7165 cfs	2.3 %
8/21	5.1 in/hr	2.26 in	0.97 cfs	2975 cfs	1.2 %
	UNTREATED				
4/16	4.0 in/hr	0.60 in	0.53 cfs	3201 cfs	3.2 %
4/21	0.2 in/hr	0.23 in	0.06 cfs	199 cfs	0.5 %
5/8	6.0 in/hr	0.63 in	0.45 cfs	1441 cfs	1.4 %
5/11	0.1 in/hr	0.16 in	0.04 cfs	1335 cfs	5.0 %
6/3	1.9 in/hr	0.97 in	0.44 cfs	3430 cfs	2.1 %
6/8	3.4 in/hr	0.97 in	0.47 cfs	9334 cfs	5.7 %
8/6	2.5 in/hr	2.41 in	2.18 cfs	17962 cfs	4.4 %
8/21	2.9 in/hr	3.25 in	1.35 cfs	29324 cfs	5.4 %
10/4	1.8 in/hr	2.31 in	0.85 cfs	27354 cfs	7.0 %

Results shown in Tables 3 and 4 indicate that water quality from runoff was better than had been anticipated and runoff totals were less than predicted, especially where good practices and management were used. Both subsurface tile and grassed waterways appear to reduce runoff and reduce nutrient levels in runoff.

The watershed sites have been used to train students, farmers and professionals. One masters level graduate student was trained on installation and data collection. He managed those activities during the second season. He also conducted much of the data analysis covered in this report and prepared the addendum report on the hydrologic modeling. Three undergraduate students also participated in the project through fabrication and installation of equipment, data collection, and analysis of data. Project field sites were visited and discussed as part of field trips for the senior level Natural Resource Engineering class at SDSU. Results will be used in class presentations and lab assignments. Several groups of farmers and resource professionals have toured the field sites. Information on the project was also presented at the SD Water and Soil Conference in March 2002.

Summary and Conclusions

Nitrate levels averaged lower in surface runoff samples than in tile outflow. Water quality samples from tile outflow collected over two summers ranged from less than two ppm to nearly 20 ppm. Nitrates in runoff water ranged up to 8.7 ppm. Average nitrate concentrations in tile outflow were not excessive. Good nitrogen management should be able to maintain average nitrogen concentrations at acceptable levels. Phosphorus levels in tile outflow were low at about the minimum detection level. Phosphorus concentrations in tile outflow should not pose any water quality risks.

Total phosphorus levels in the surface runoff were lower than expected ranging from less than one ppm to about 13 ppm. Only one sample was over 3.8 ppm. Average phosphorus levels were lower in the runoff water from the grassed waterway that had subsurface tile than in the untreated waterway.

TKN in the surface runoff was considerably higher than the nitrate nitrogen. Levels seemed to correlate with phosphorus levels. TKN levels were likely associated with organic material and sediment in the runoff water.

No runoff occurred in 2001 during the time that the samplers were installed in the waterways. Runoff was not measurable on the tile-only watershed even though rainfall events were essentially identical as the untreated watershed. In 2002 only two runoff events occurred on the watershed that had the grassed waterway accompanied by tile. Runoff was common in the untreated watershed and nine events were recorded when flow could be quantified. Runoff events on the untreated watershed were triggered with less than 0.2 inches of rainfall.

Observations of the untreated watershed in 2002 indicated crop productivity loss and restriction of field operations even with small rainfalls. This occurred during periods with less than normal rainfall. Runoff events produced erosion and sediment transport. The other two watersheds did not show similar problems. The subsurface tile drainage reduced the amount and severity of runoff from those watersheds. The watershed with the grassed waterway had steeper slopes and a higher risk of runoff (see the addendum report), but still had fewer runoff events, and the runoff had lower levels of contaminants than the waterway without tile.

Recommendations

The study should be continued on the watersheds, especially the two that had runoff in 2002, to document surface and tile runoff with different environmental conditions. Additional study should be done to document runoff conditions from a broader range of small agricultural watersheds. Finally, research is needed to be able to model the hydrology of small waterways that are common in Eastern South Dakota.

Appendix A

Aerial Maps and Topographic Maps of Watersheds

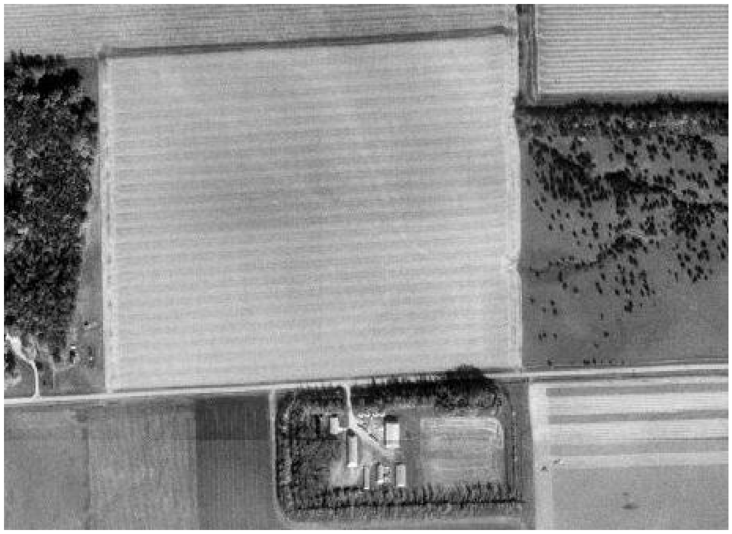


Figure A1 – Watershed with Grass and Tile Waterway.

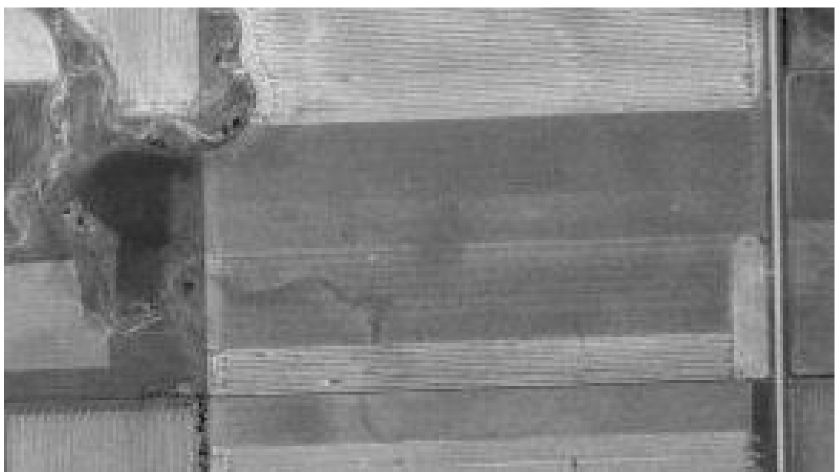


Figure A2 – Watershed with Tile-Only Waterway.

Figure A3 – Untreated Watershed.

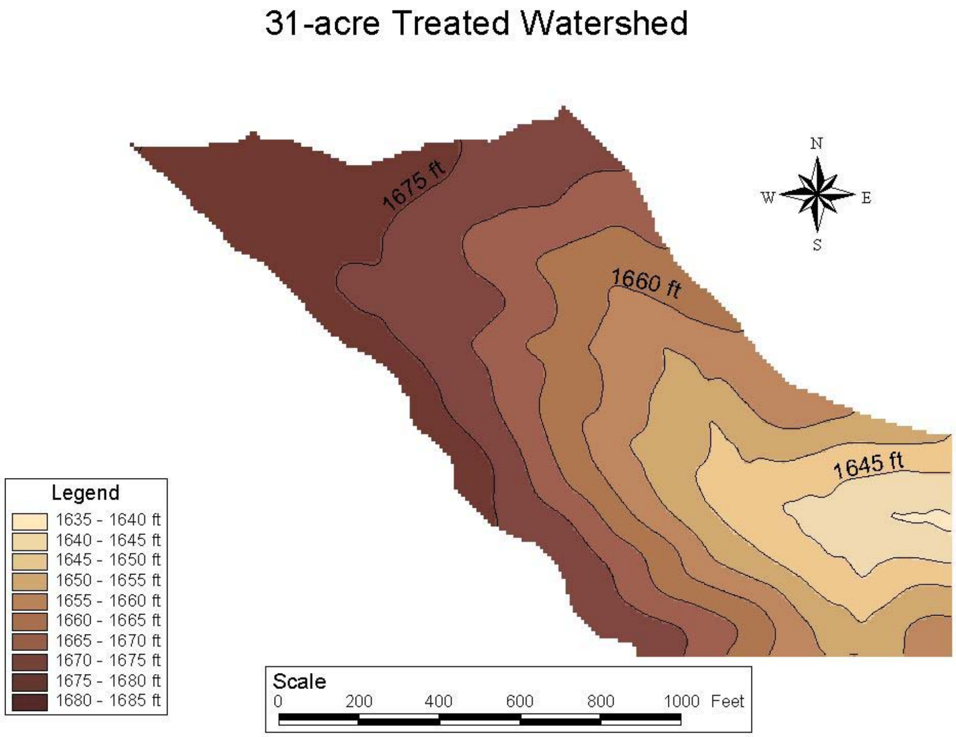


Figure A4 – Topographic Map of Grass/Tile Watershed.

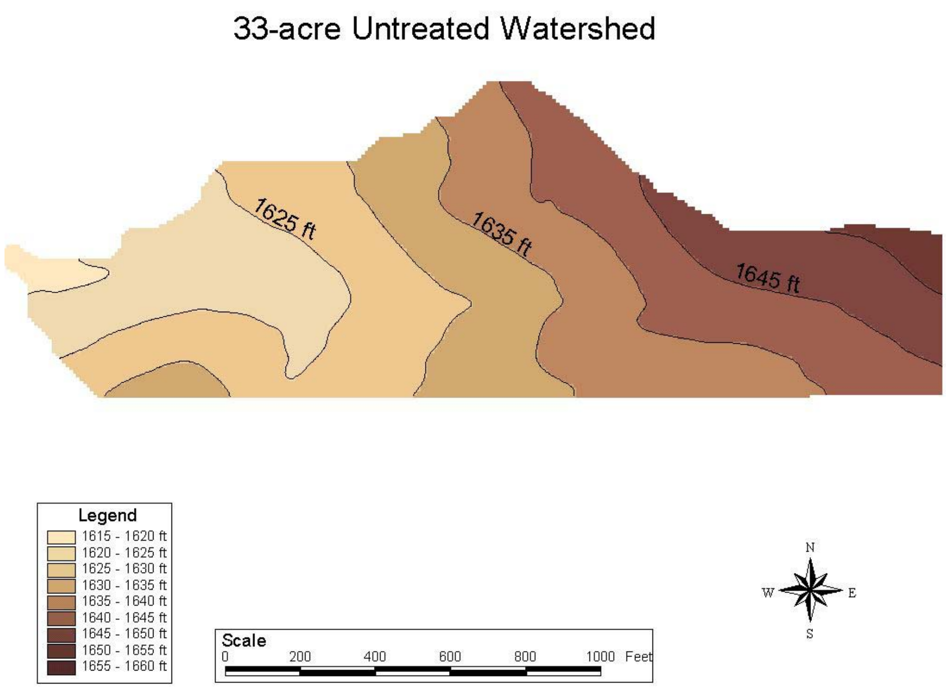


Figure A5 – Topographic Map of Watershed with Tile-Only Waterway.

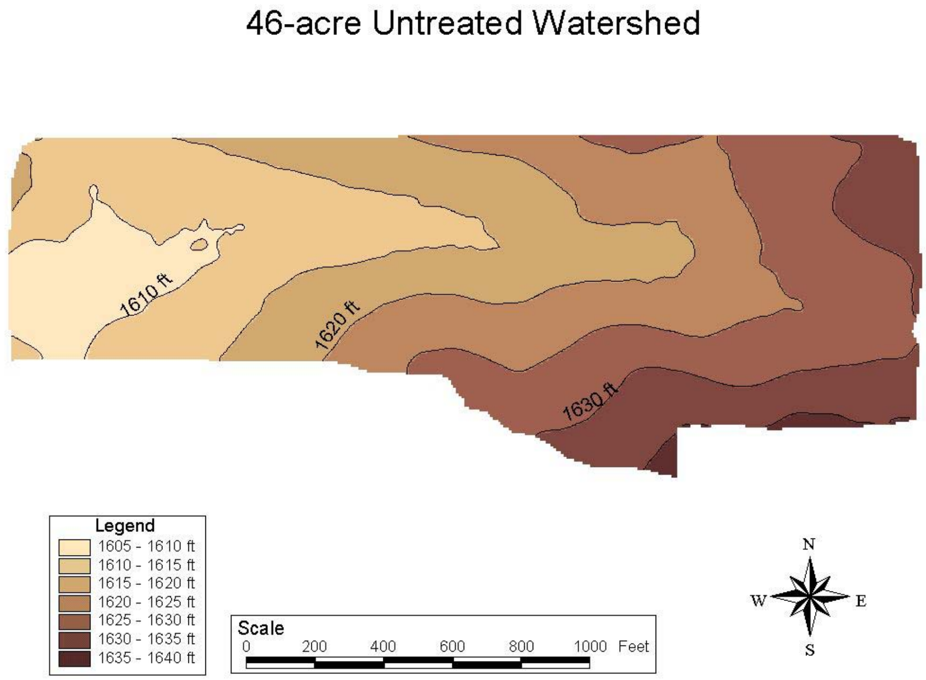
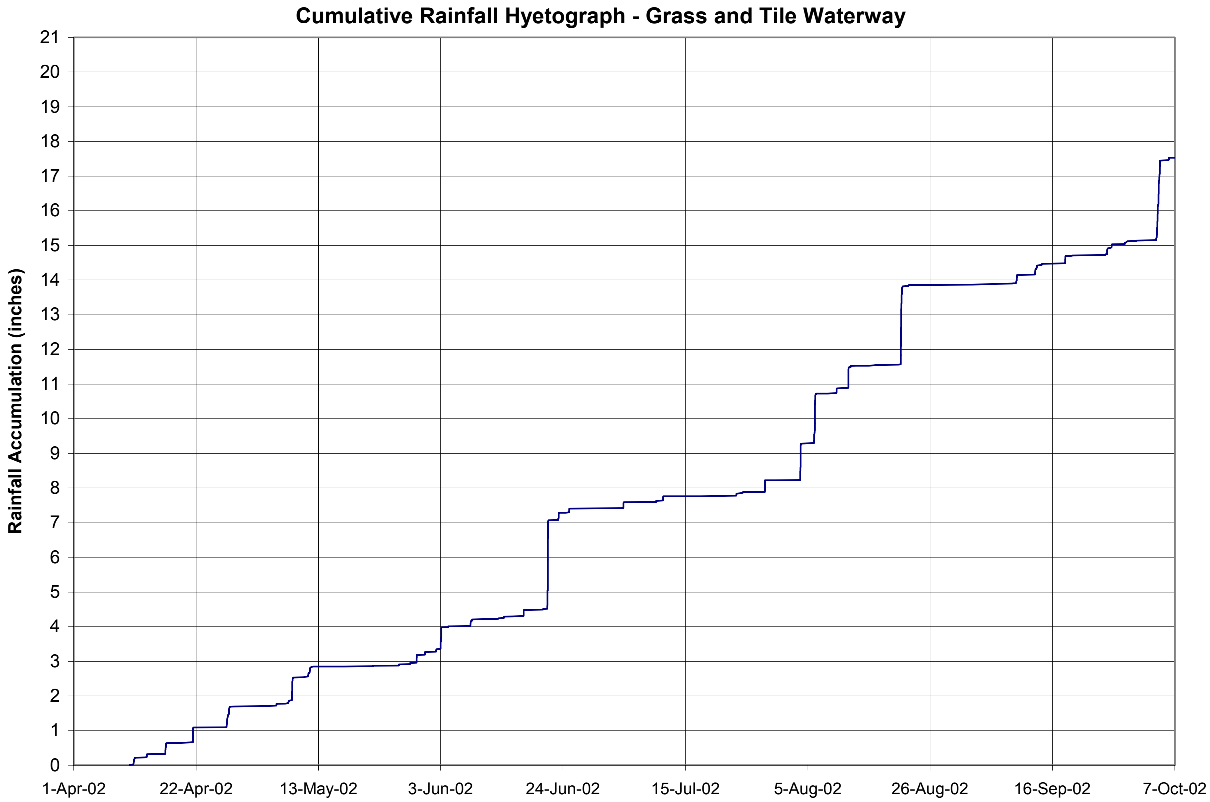
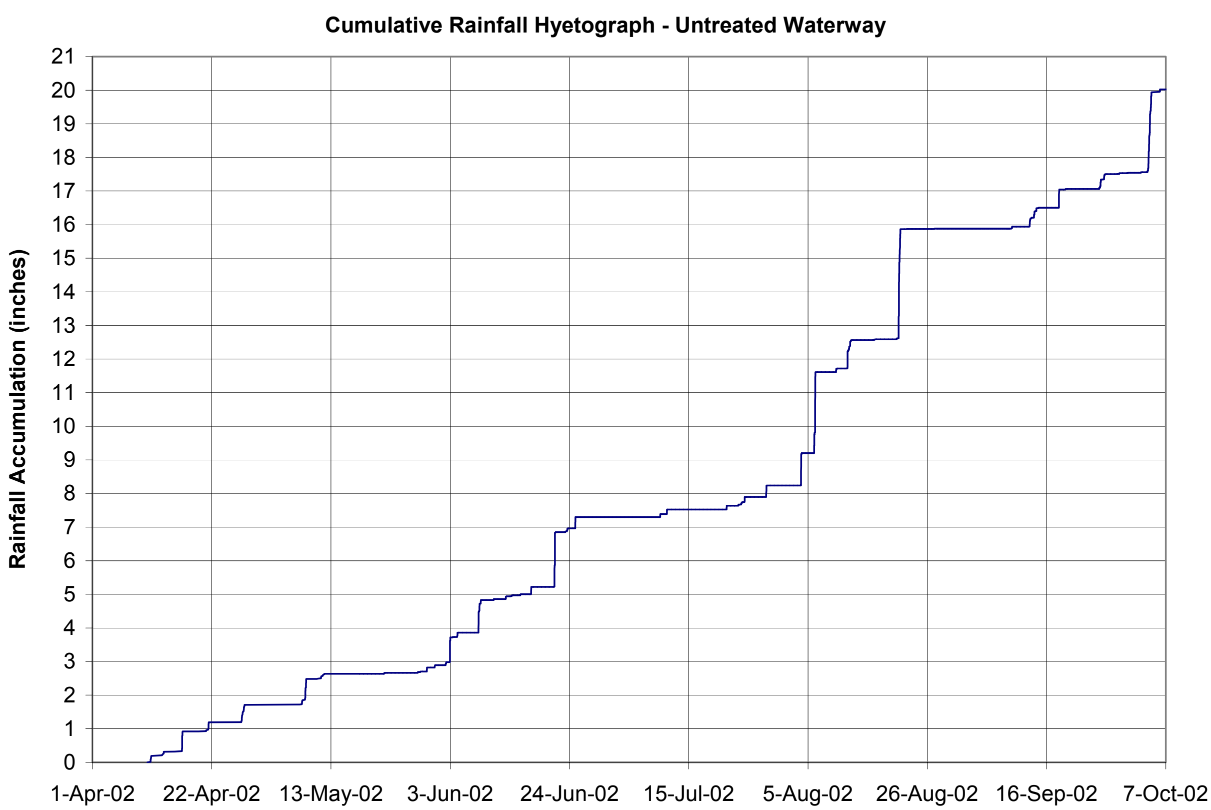


Figure A6 – Topographic Map of Untreated Watershed.

Appendix B

Precipitation and Runoff Hydrographs


Cumulative Rainfall Hyetograph - Grass and Tile Waterway
Rainfall Accumulation (inches)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
1-Apr-02
22-Apr-02
13-May-02
3-Jun-02
24-Jun-02
15-Jul-02
5-Aug-02
26-Aug-02
16-Sep-02
7-Oct-02


Cumulative Rainfall Hyetograph - Untreated Waterway
Rainfall Accumulation (inches)
0
1
2
3
4
5
6
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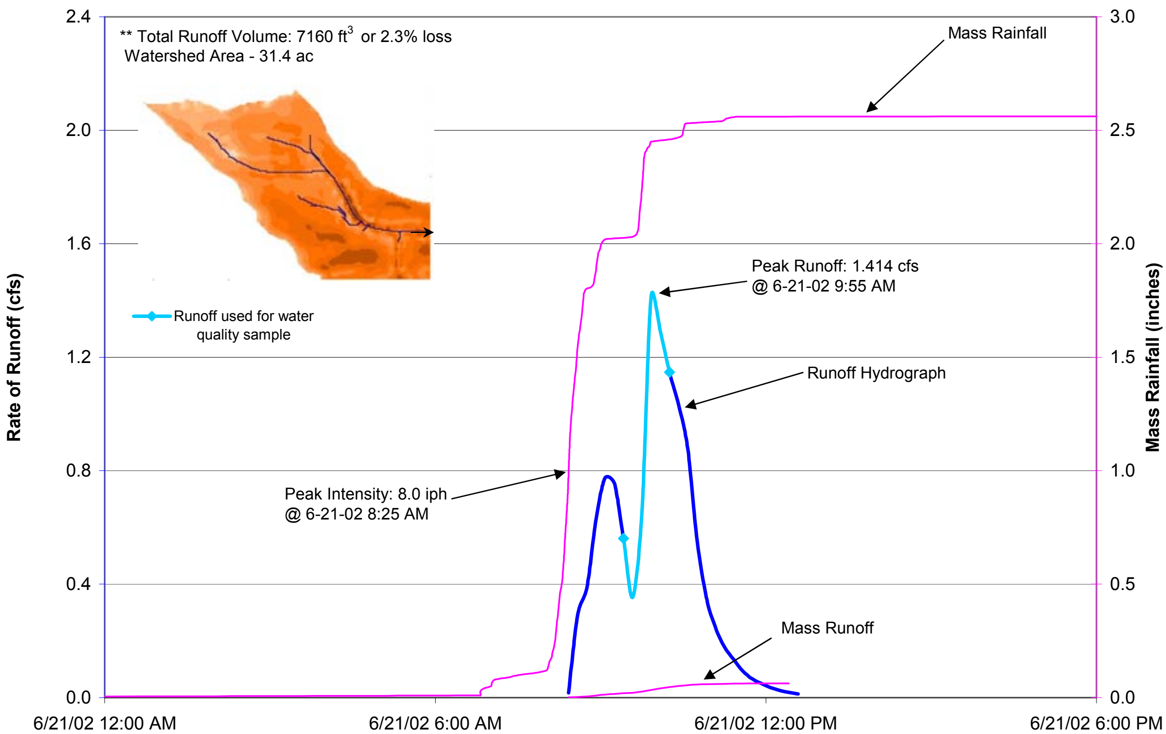
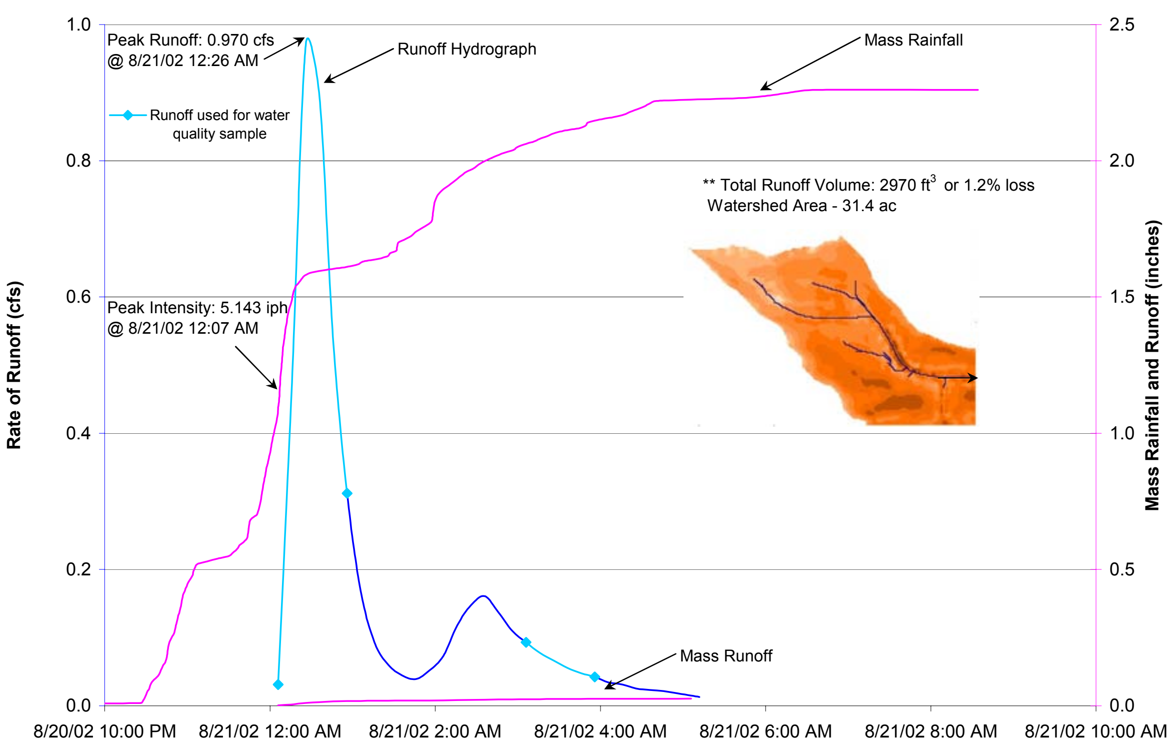
8
9
10
11
12
13
14
15
16
17
18
19
20
21
1-Apr-02
22-Apr-02
13-May-02
3-Jun-02
24-Jun-02
15-Jul-02
5-Aug-02
26-Aug-02
16-Sep-02
7-Oct-02

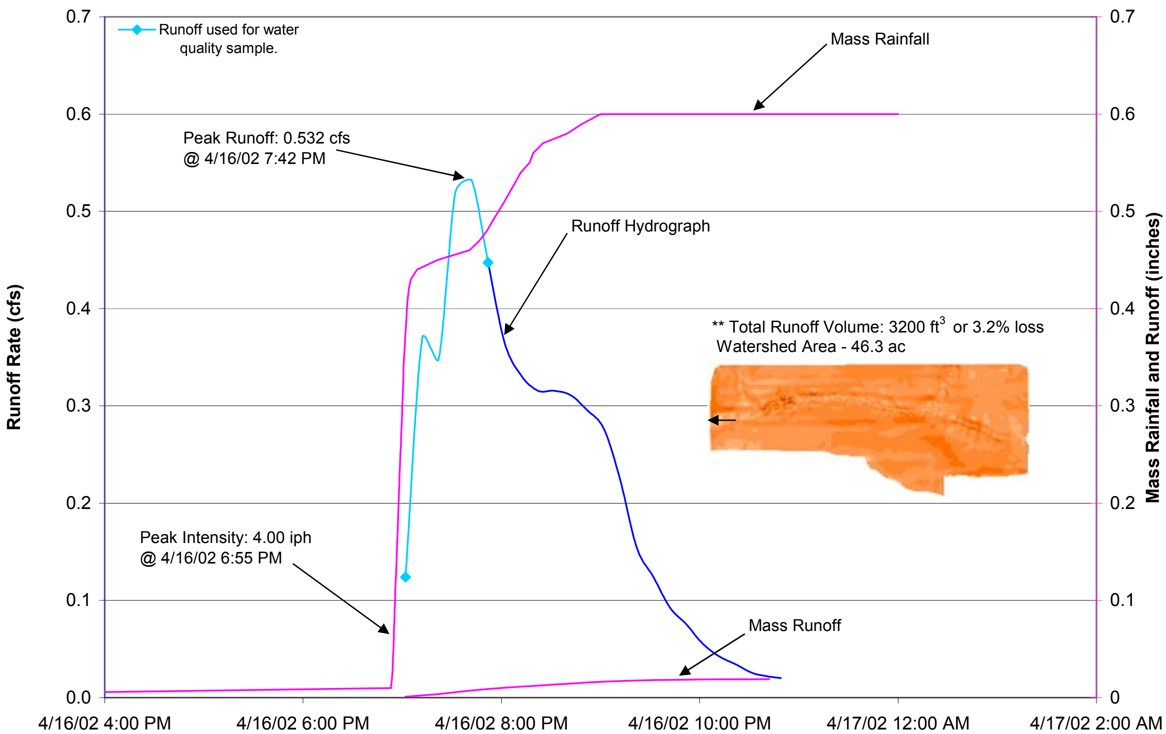
Precipitation and Runoff from June 21, 2002 Storm Event at Grass/Tile Watershed



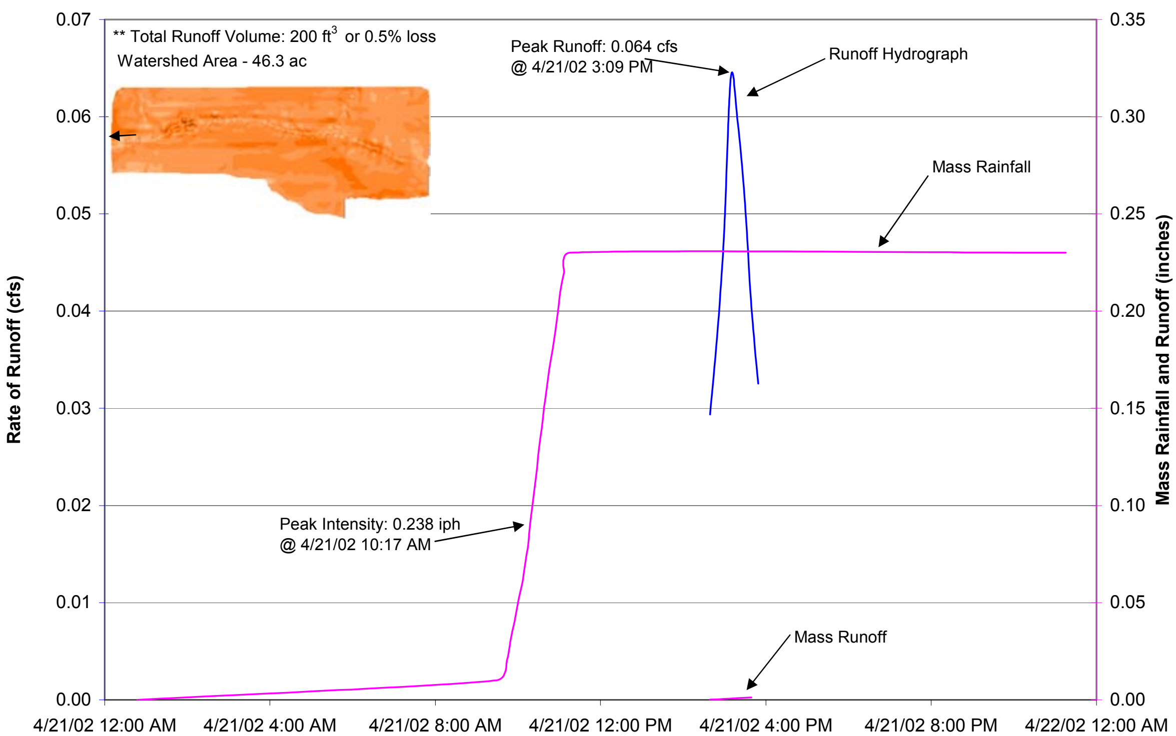
Precipitation and Runoff from August 21, 2002 Storm Event at Grass/Tile Watershed



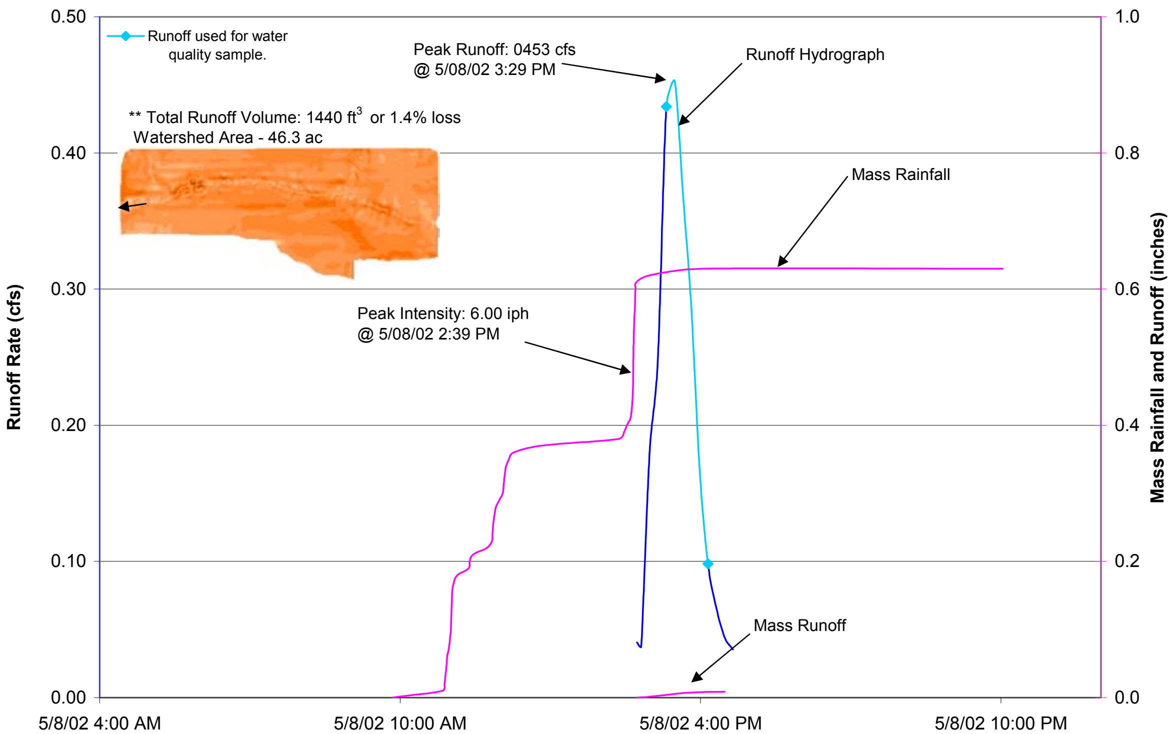
Precipitation and Runoff from April 16, 2002 Storm Event at Untreated Watershed



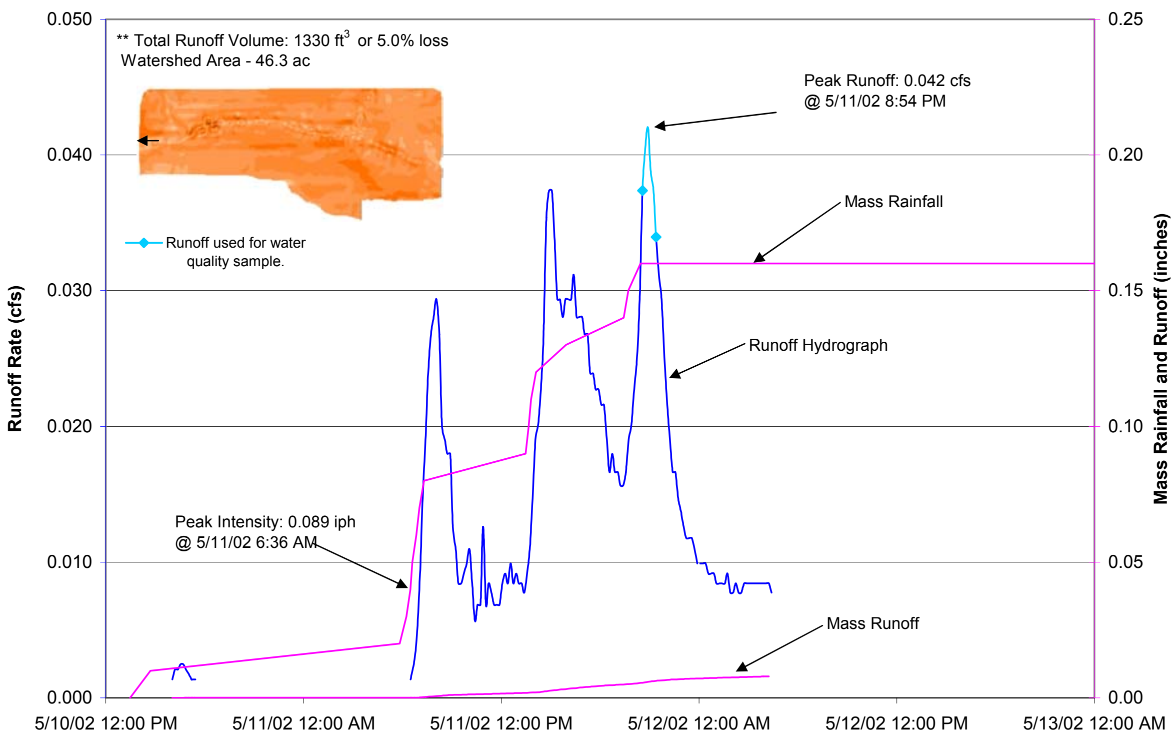
Precipitation and Runoff from April 21, 2002 Storm Event at Untreated Watershed



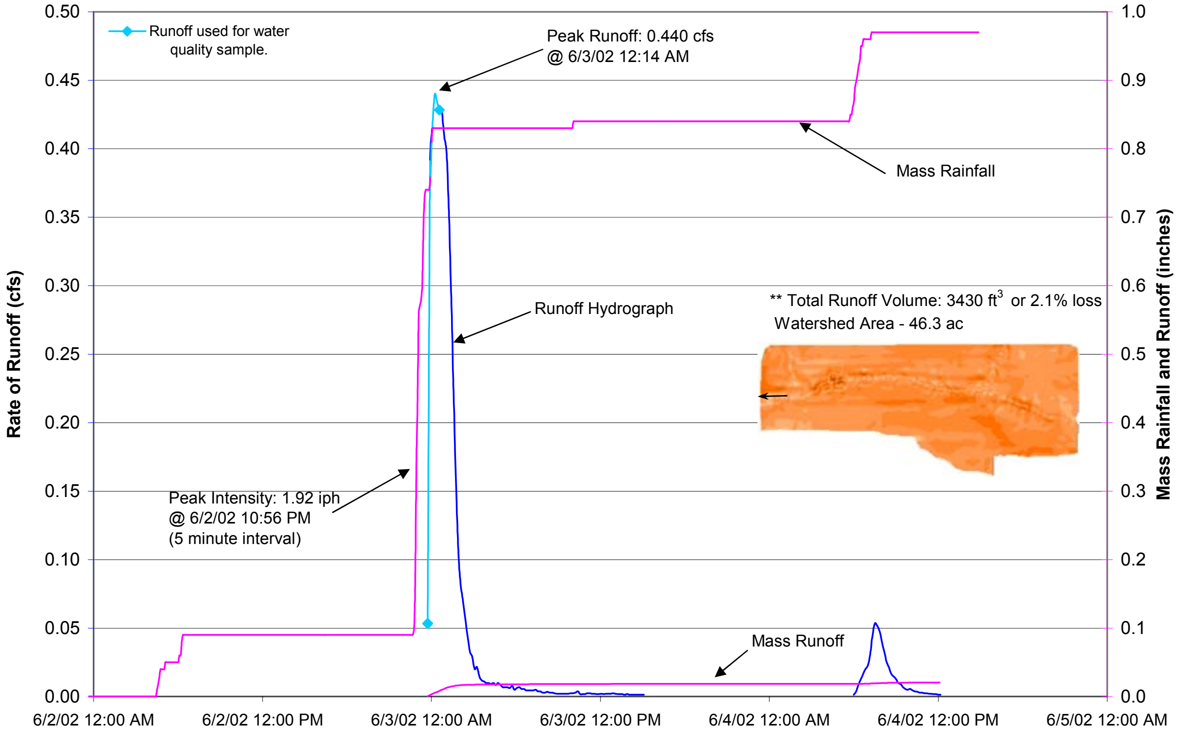
Precipitation and Runoff from May 8, 2002 Storm Event at Untreated Watershed



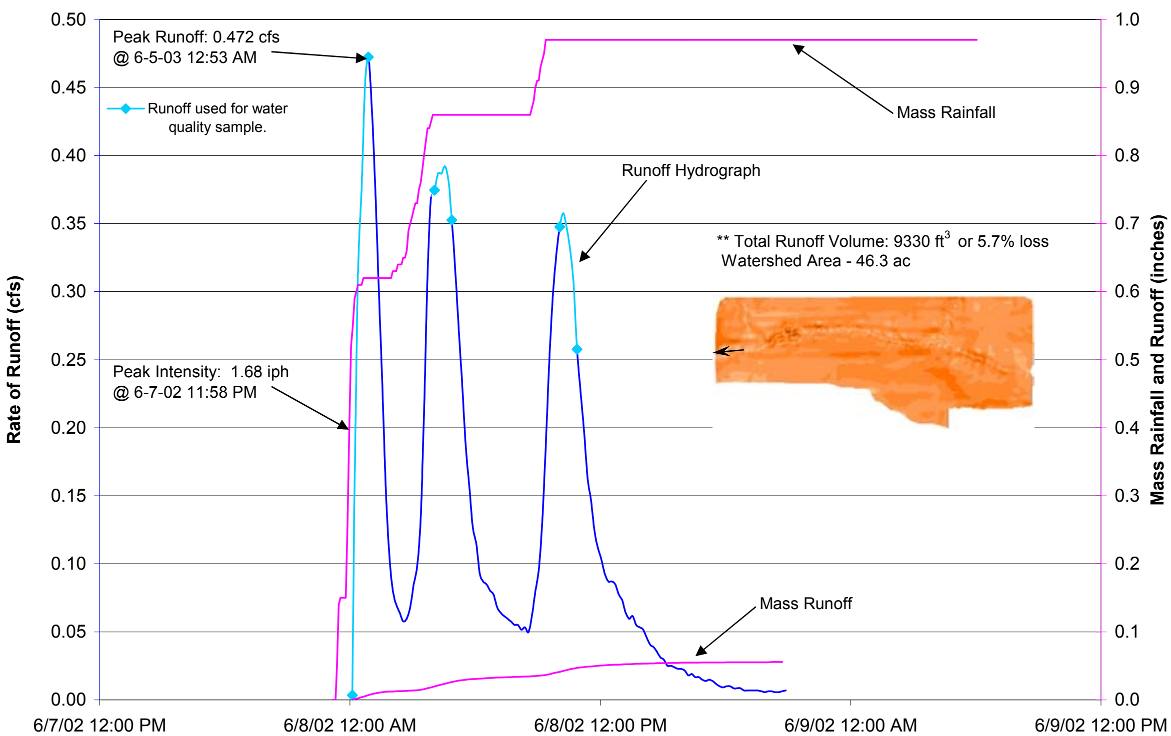
Precipitation and Runoff from May 11, 2002 Storm Event at Untreated Watershed



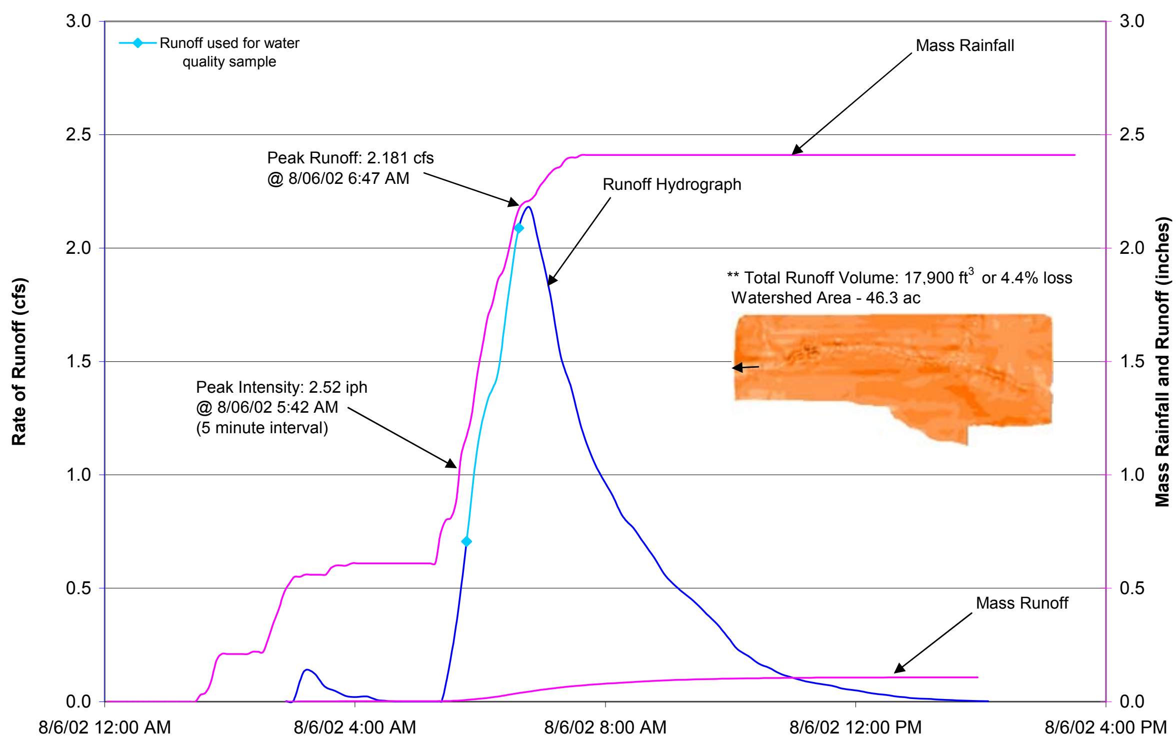
Precipitation and Runoff from June 3, 2002 Storm Event at Untreated Watershed



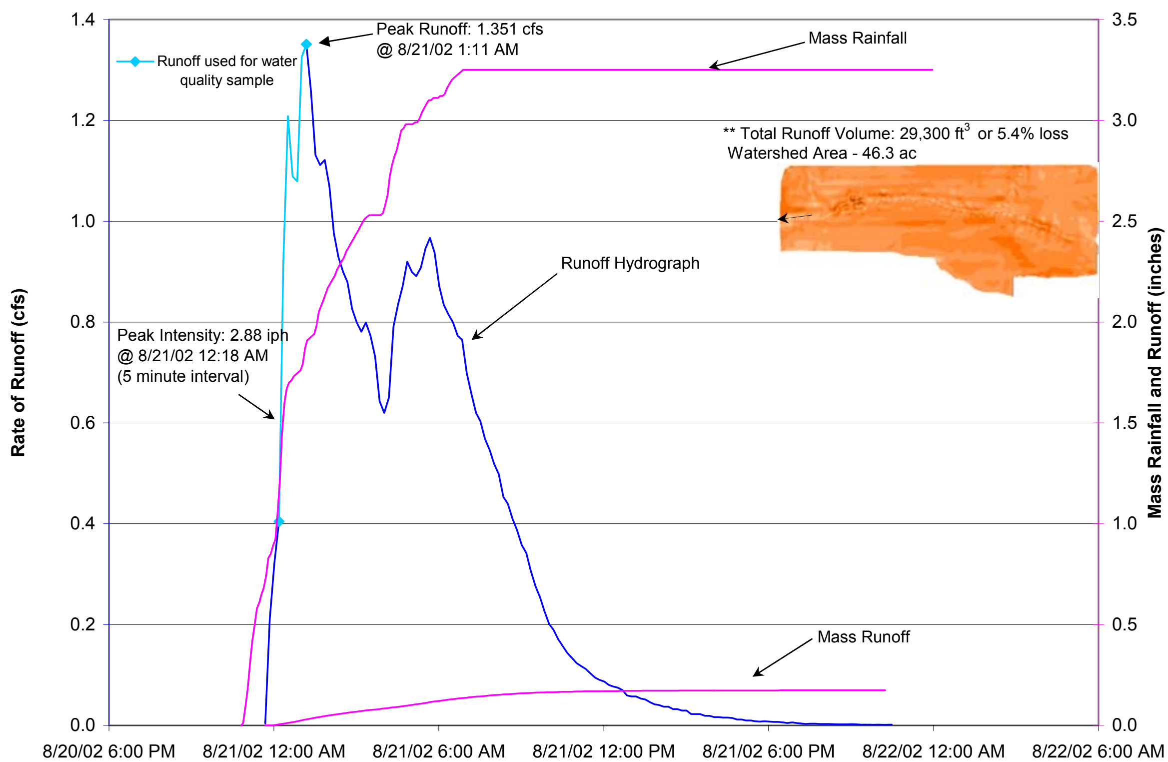
Precipitation and Runoff from June 8, 2002 Storm Event at Untreated Watershed



Precipitation and Runoff from August 6, 2002 Storm Event at Untreated Watershed



Precipitation and Runoff from August 21, 2002 Storm Event at Untreated Watershed



Precipitation and Runoff from October 4, 2002 Storm Event at Untreated Watershed